FIG.1

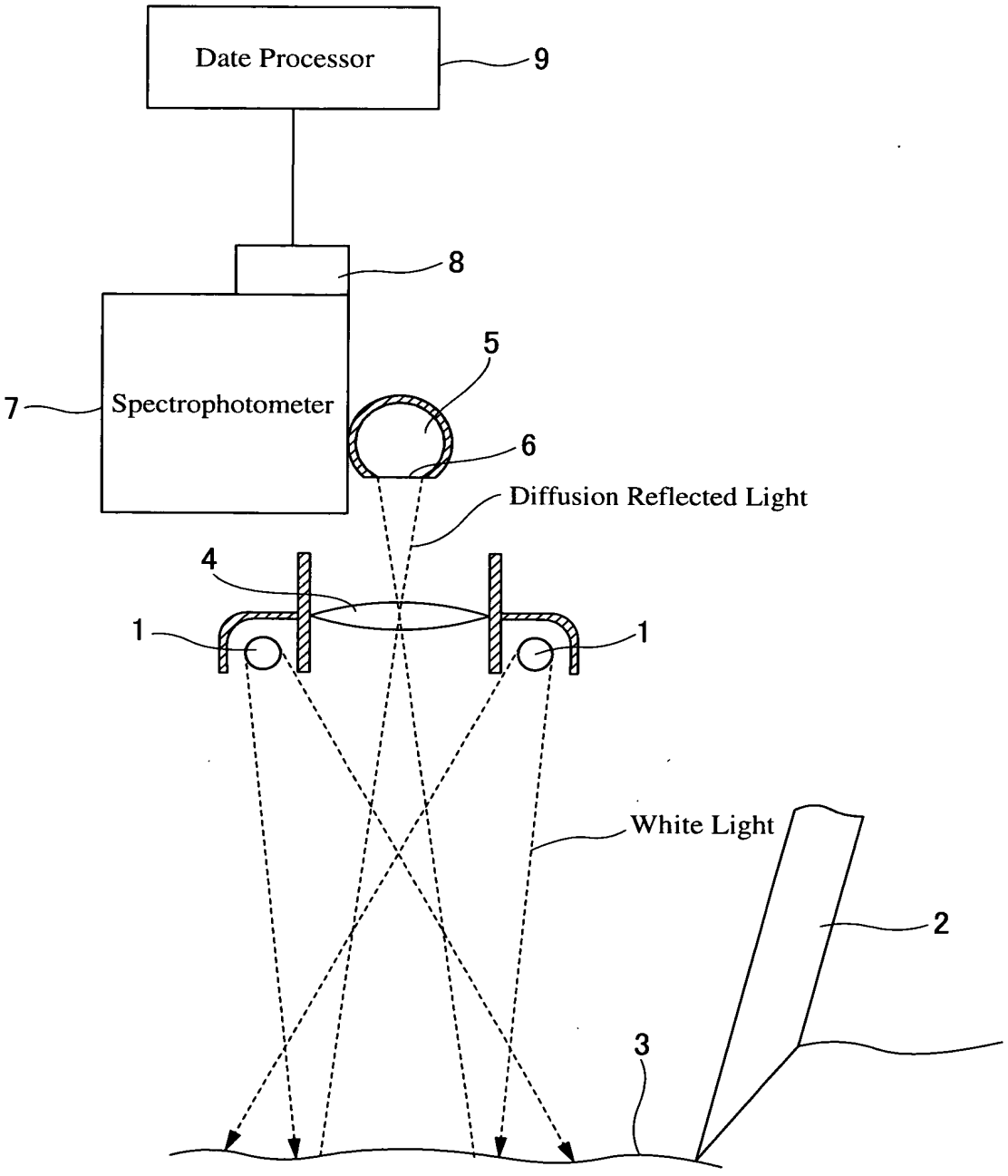

Date Processor
9
8
5
7
Spectrophotometer
6
Diffusion Reflected Light
4
1
1
White Light
2
3

FIG.2

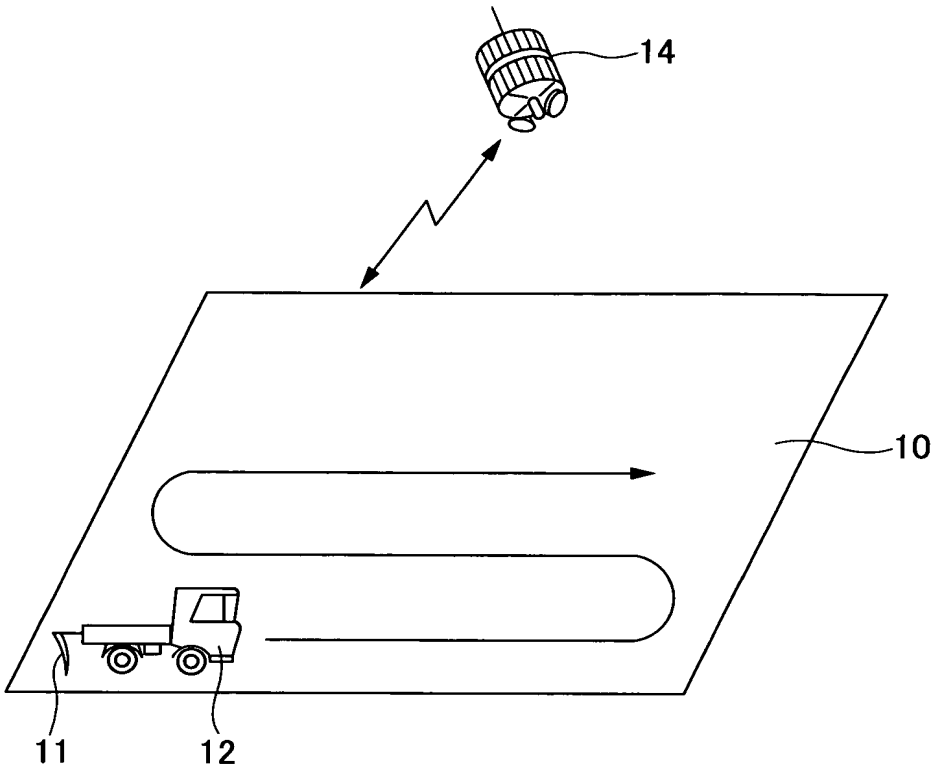


FIG.3

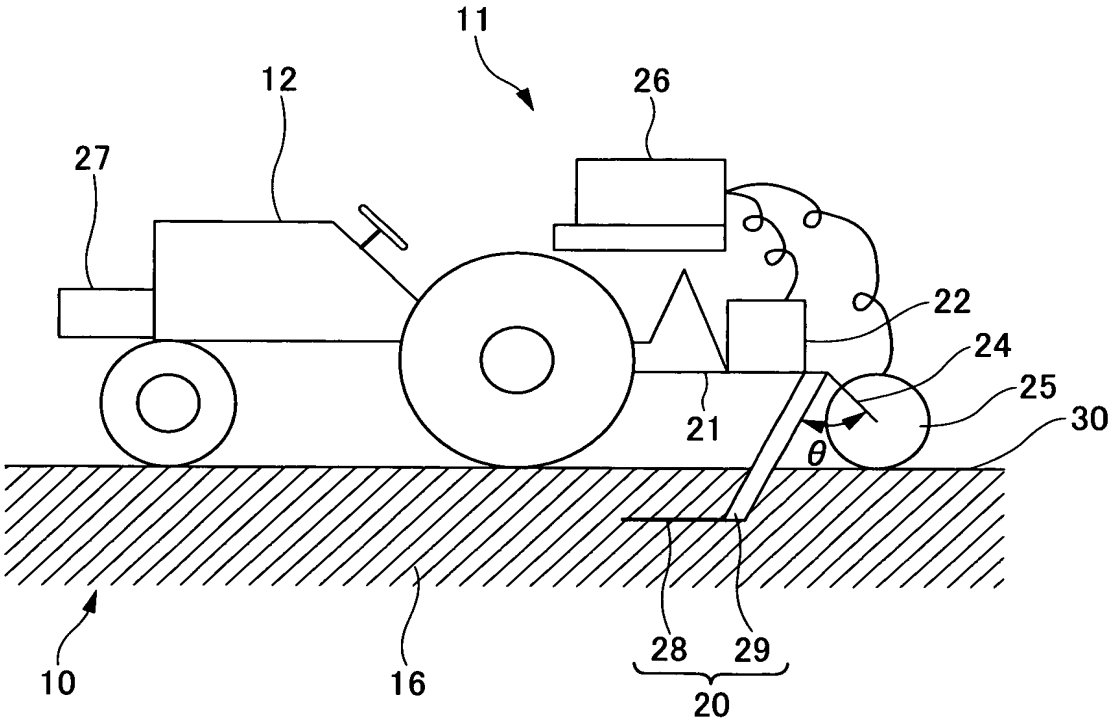


FIG.4

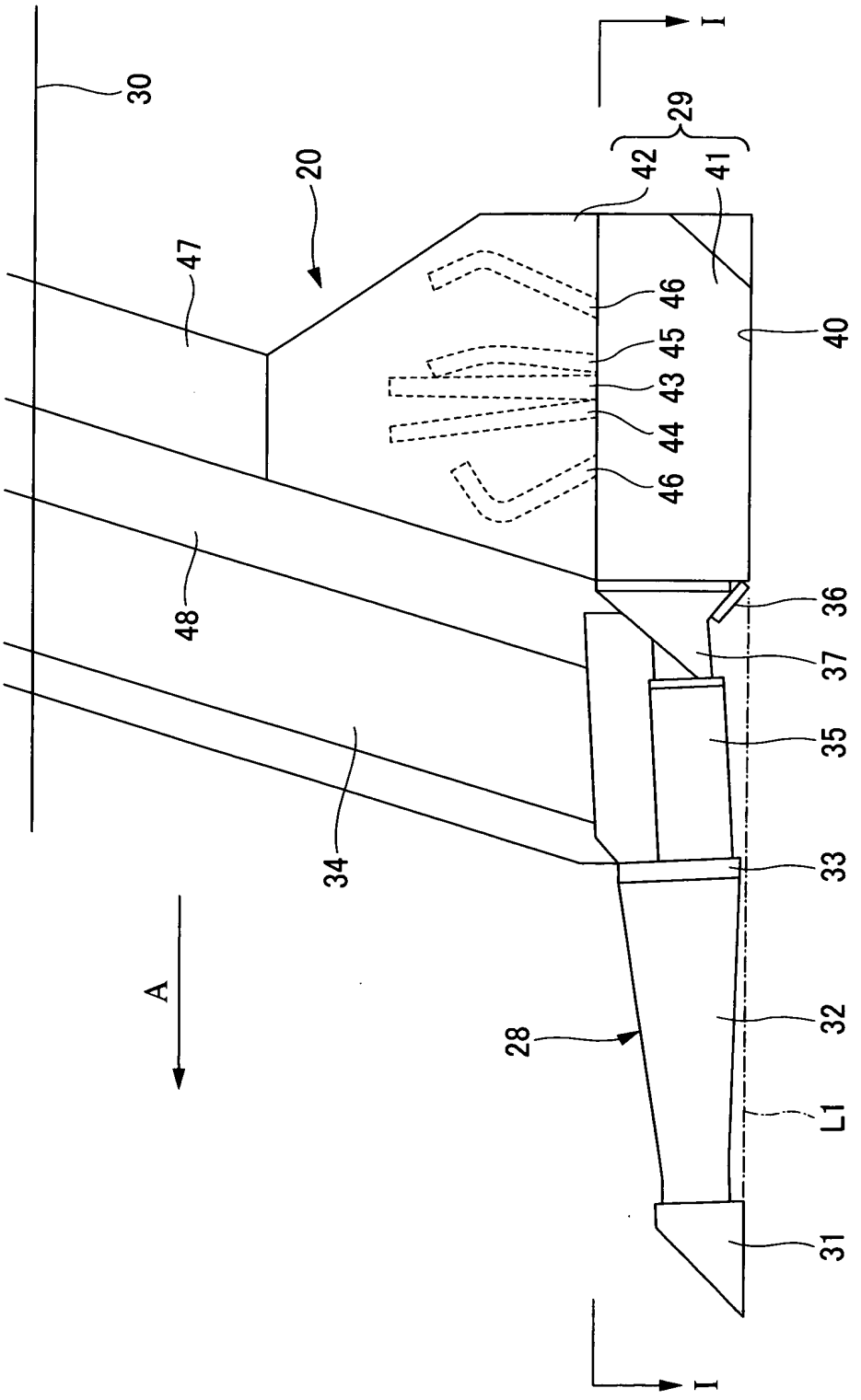


FIG.5

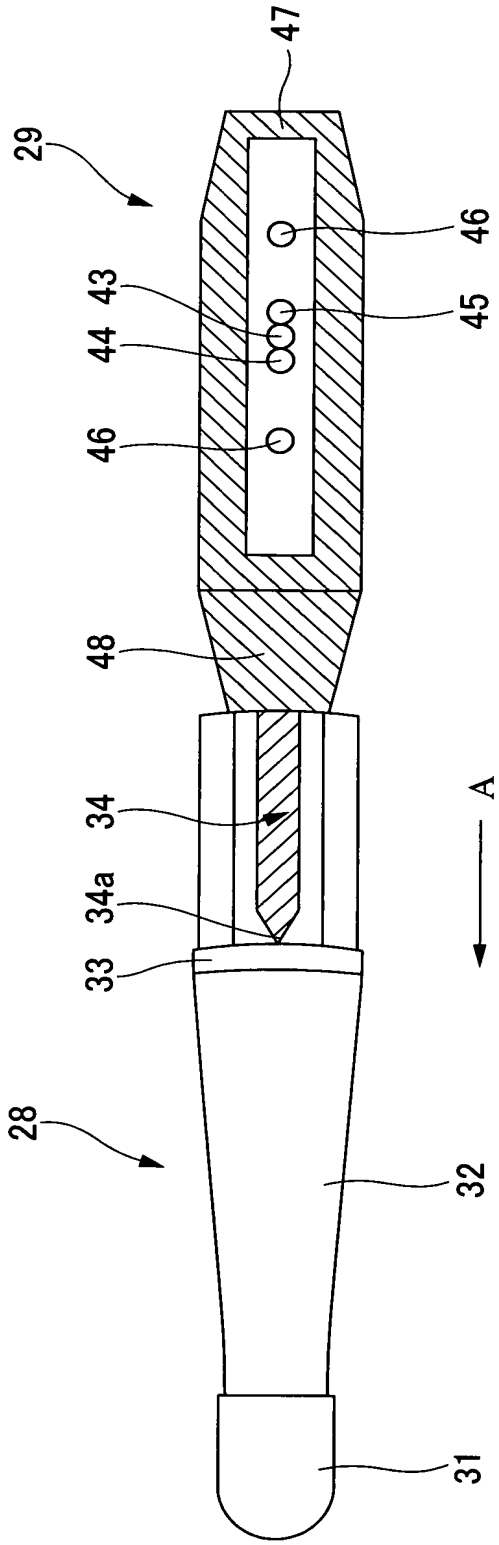


FIG.6

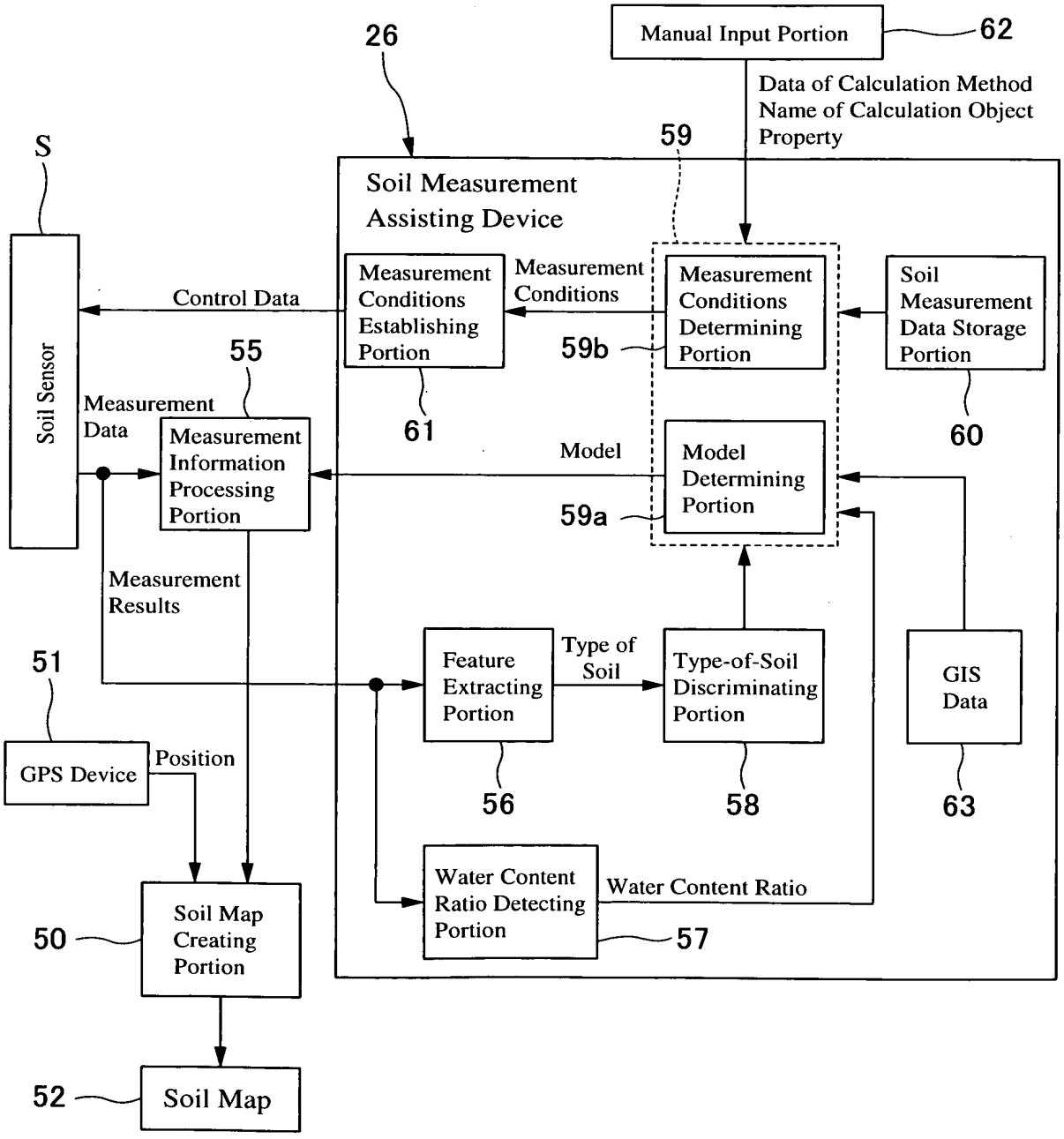

Manual Input Portion
62
26
Data of Calculation Method
Name of Calculation Object
Property
59
S
Soil Measurement
Assisting Device
Soil Sensor
Measurement
Conditions
Establishing
Portion
Measurement
Conditions
Measurement
Conditions
Determining
Portion
Soil
Measurement
Data Storage
Portion
Control Data
55
59b
Measurement
Data
Measurement
Information
Processing
Portion
61
60
Model
Model
Determining
Portion
59a
Measurement
Results
51
Feature
Extracting
Portion
Type of
Soil
Type-of-Soil
Discriminating
Portion
GIS
Data
GPS Device
Position
56
58
63
Water Content
Ratio Detecting
Portion
Water Content Ratio
57
50
Soil Map
Creating
Portion
52
Soil Map

FIG.7

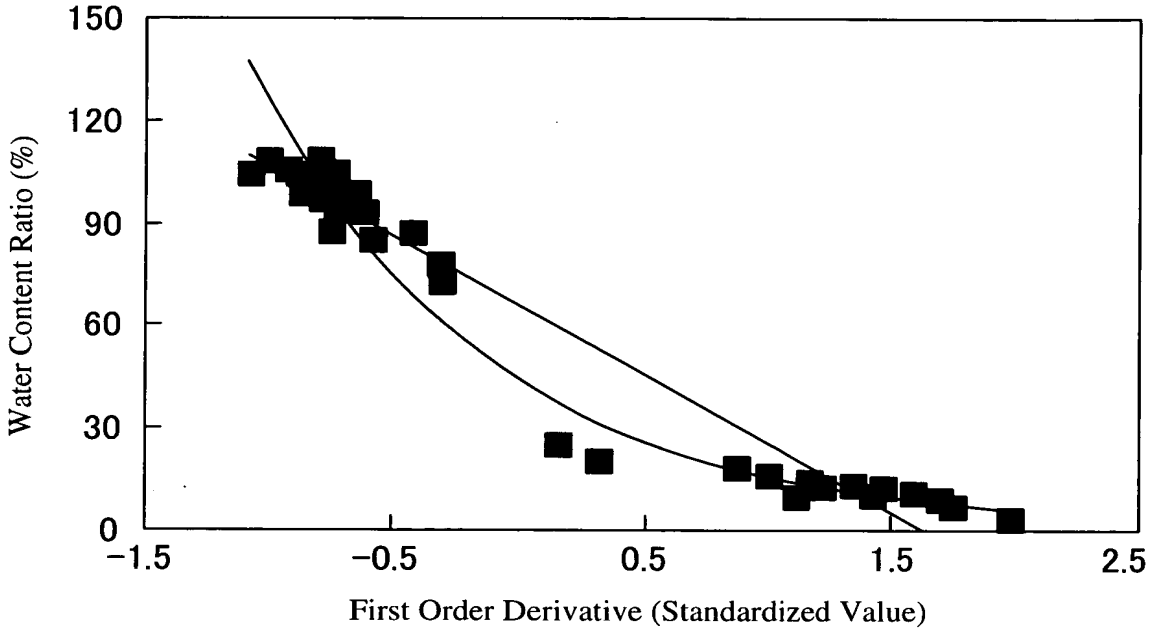

150
120
90
60
30
0
Water Content Ratio (%)
−1.5
−0.5
0.5
1.5
2.5
First Order Derivative (Standardized Value)

FIG.8

Color of Soil and Color-Causing Substances

Soil Color	Main Coloring Substances	Soil
Black	* Organic Matter · Humus Iron Sand Black Scoria [Manganese Speckling, Sulfides]	Muck Soil ·E Peat Soil, Gley Andisol Dark-Colored Andisol (Humus Volcanic Ash Soil, Andisol) Sandy Soil Containing Large Amount of Iron Sand(Immature) Basalt Volcanic Ejector(Raw Soil)
Red ~ Brown ~ Yellow	* Ferric Oxide Minerals (Iron Oxide) Manganese [Speckled Iron]	Red Soil Light-Colored Andisol (Volcanic Ash Soil, Light-Colored Andisol) Brown Forest Soil, Yellow Soil Dark Red Soil
Blue ~ Green	* Ferrous Compounds (Reduced Iron) [Iron Sulfide, Pyrite, Etc.]	Gley Soil(Blue Soil Having Poor Drainage) Strong Gley Soil(Wet Rice Field), Gley Soil (Semi-Wet Rice Field)
Gray ~ White	* Extremely Small Iron Oxide Content *Oxidization Process of Blue Muddy Layer *Accumulation of Salts	Podzol Soil (Gray Soil), Degraded Ferro-Deficient Paddy Field Decomposed Granite Soil, Silas, Sandy Soil(White Sand) Gray Lowland Soil(Dry Rice Field) Salty Soil

(Source : Agricultural Technology System Compiled Soil Fertilizers, Vol.1 Rural Culture Association)

FIG.9

Input				Output	
Name of Measurement Object Property	Water Content Ratio	Type of Soil	Measurement Method	Model	Measurement Conditions
NO_3-N Concentration	Low (3~26%db) Note 1)	Kanto Loam (SILT 28%, CLAY 20%, SAND 52%)	Method 1 : White light is shone onto surface of soil made even by a soil flattening blade, and the reflected light spectrum is measured	NO_3-N Concentration= $A+\Sigma Bi \cdot \exp(Ci \cdot Xi)$ Where A, Bi, Ci are coefficients. The value of each coefficient is as follows. $Yi=dXi / d\lambda$ A=3.96 B1=6.16 E-3 B2=0.241 B3=4.67 E-4 C1=6.27 C2=1.56 C3=6.48	The amount of reflected light Xi is measured for each of the following wavelengths. (1)824nm (2)1280nm (3)1768nm
NO_3-N Concentration	High (72~120% db)	Kanto Loam (SILT 28%, CLAY 20%, SAND 52%)	Same as above	NO_3-N Concentration= $A+\Sigma Bi \cdot \exp(Ci \cdot Xi)$ $Yi=dXi / d\lambda$ Where A, Bi, Ci are coefficients. A=0.31 B1=0.243 B2=3.31 E-5 B3=4.64 C1=1.75 C2=7.59 C3=0.127	The amount of reflected light Xi is measured for each of the following wavelengths. (1)1286nm (2)2014nm (3)2290nm

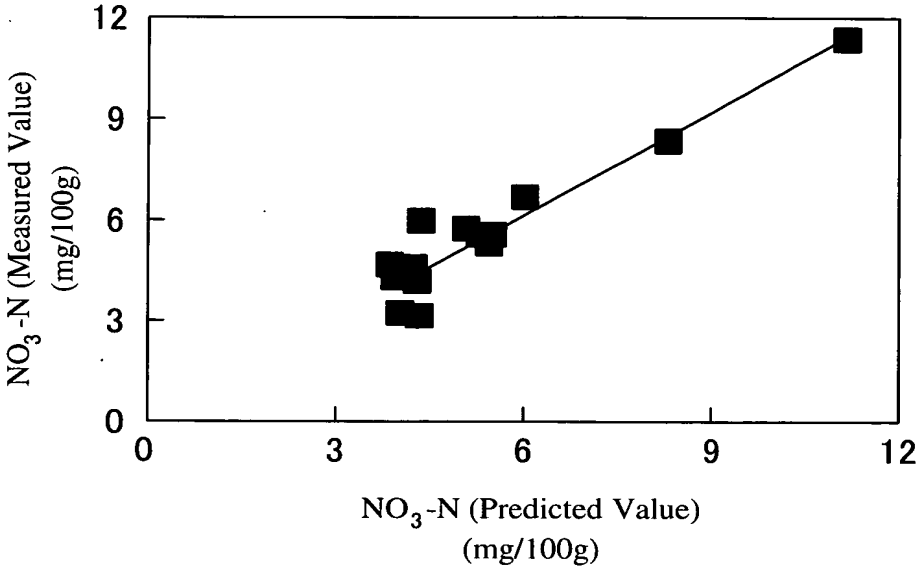
Note 1) db is the abbreviation of dry basis, and is the proportion of the weight of water with respect to the weight of solids in the soil.

FIG.10

Input				Output	
Name of Measurement Object Property	Water Content Ratio	Type of Soil	Measurement Method	Model	Measurement Conditions
Electric Conductivity	Low (2~26%db)	Upland Field	Method 1	Electric Conductivity= $A+\Sigma(Bi \cdot Xi)$ $Yi=dXi / d\lambda$ Where A, Bi are coefficients. A=128.07 B1= -7.15 B2= -16.29 B3= -7.40	The amount of reflected light Xi is measured for each of the following wavelengths. (1)2074nm (2)1948nm (3)1776nm
Accurate Water Content Ratio	Low (0~26%db)	Upland Field	Method 1	Y is the second-order derivative of X which is related to λ. The value obtained by subtracting the average from y is divided by the standard deviation to give a value which forms the standardized value W. Accurate Water Content Ratio= $5.55 \cdot W+13.2$	The amount of reflected light X is measured for each of the following wavelengths. (1)1450nm
Accurate Water Content Ratio	High (72~120% db)	Upland Field	Method 1	$Y=dX / d\lambda$ The value obtained by subtracting the average from y is divided by the standard deviation to give a value which forms the standardized value W. Accurate Water Content Ratio= $-0.096 \cdot W+9.16$	The amount of reflected light X is measured for each of the following wavelengths. (1)1850nm

FIG.11

(a)


12
9
6
3
0
0
3
6
9
12
NO_3-N (Measured Value)
(mg/100g)
NO_3-N (Predicted Value)
(mg/100g)

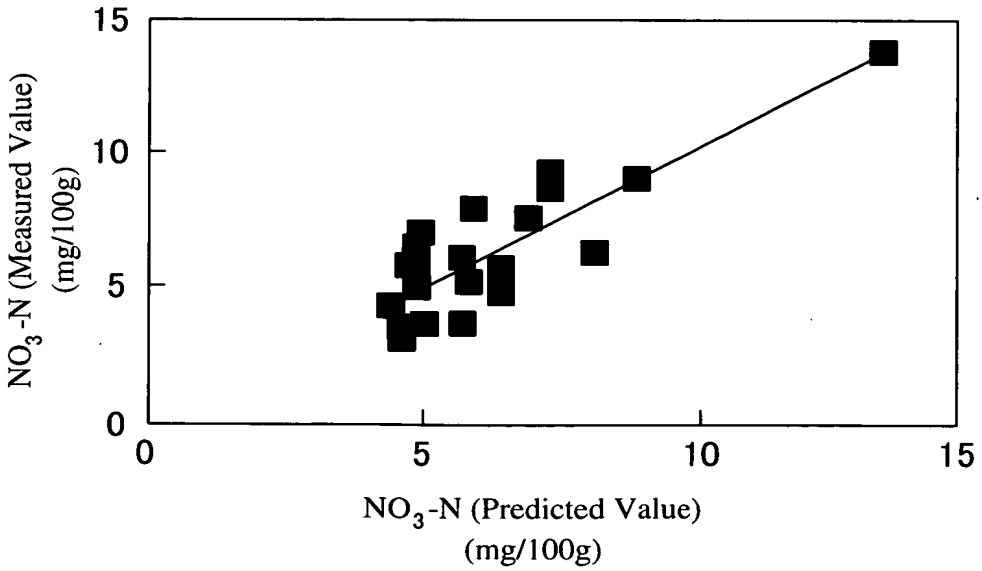
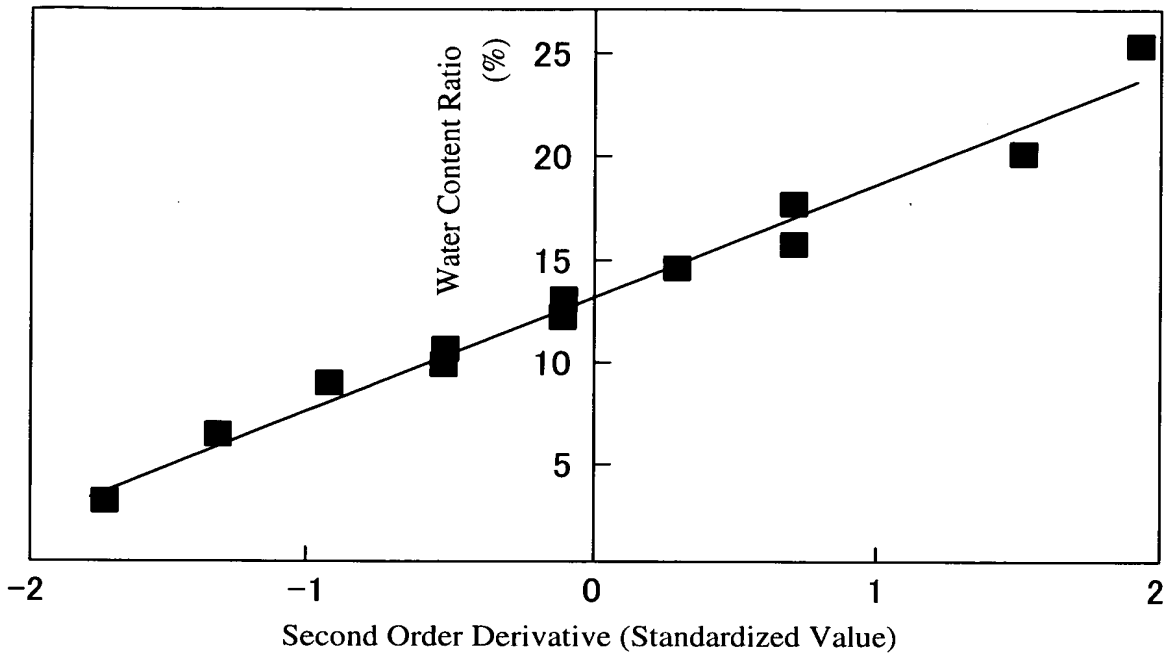

15
10
5
0
0
5
10
15
NO_3-N (Measured Value)
(mg/100g)
NO_3-N (Predicted Value)
(mg/100g)

FIG.12

(a)


Water Content Ratio (%)
25
20
15
10
5
−2
−1
0
1
2
Second Order Derivative (Standardized Value)

(b)

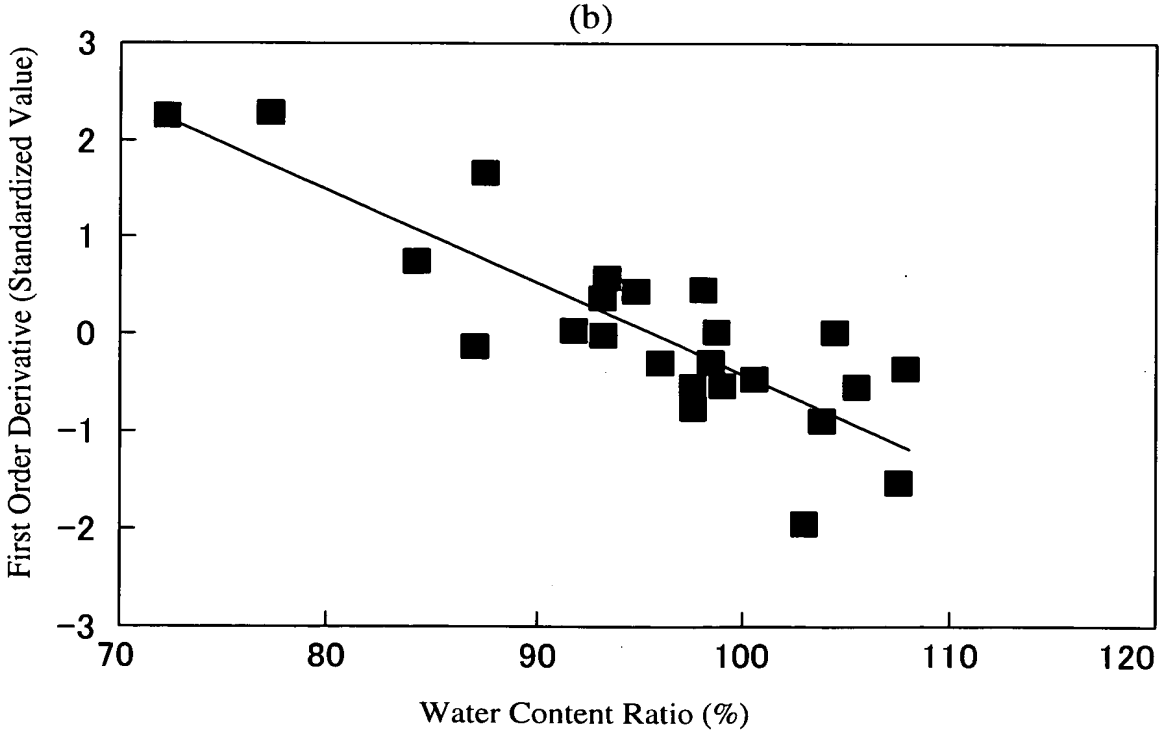
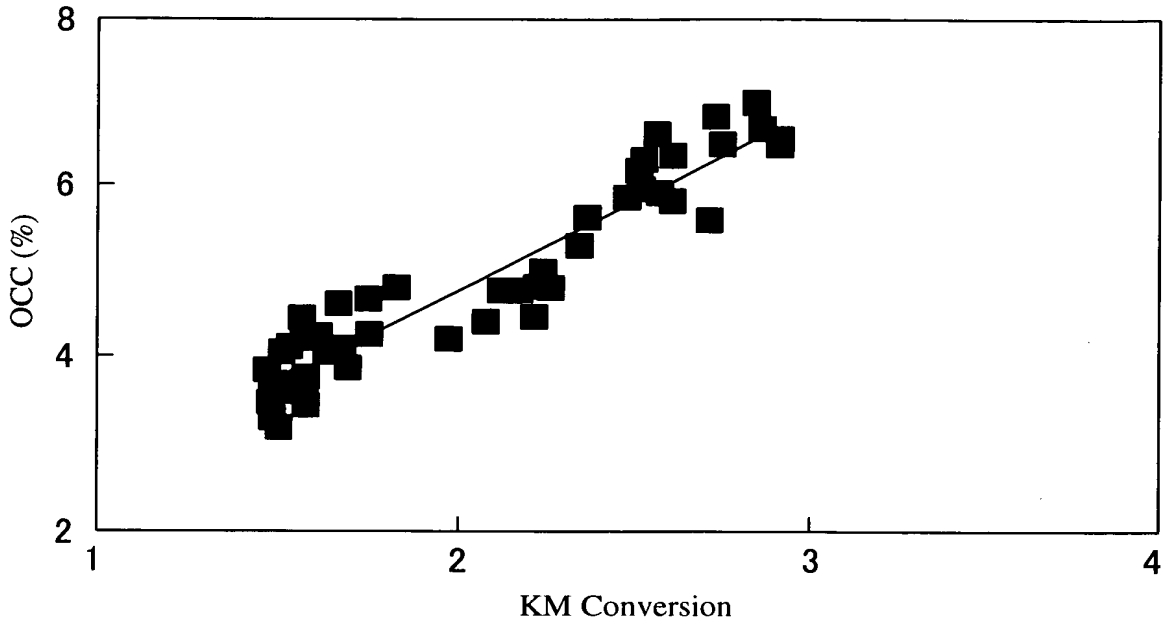

First Order Derivative (Standardized Value)
3
2
1
0
−1
−2
−3
70
80
90
100
110
120
Water Content Ratio (%)

FIG.13

(a)


8
6
4
2
OCC (%)
1
2
3
4
KM Conversion

(b)

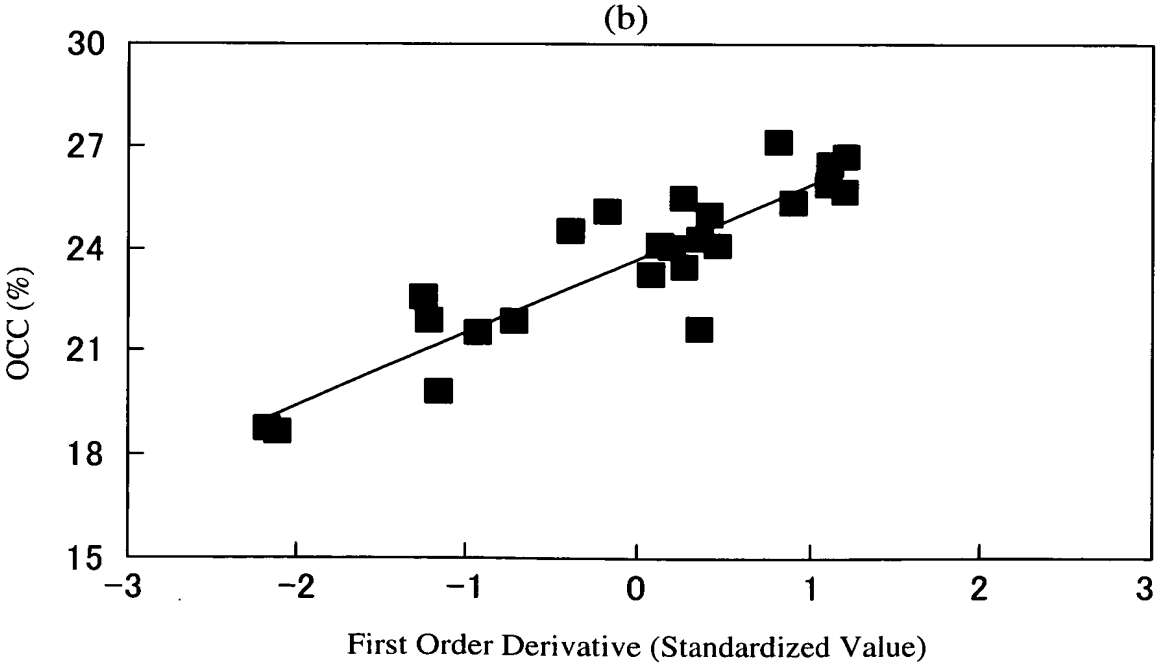

30
27
24
21
18
15
OCC (%)
−3
−2
−1
0
1
2
3
First Order Derivative (Standardized Value)

FIG.14

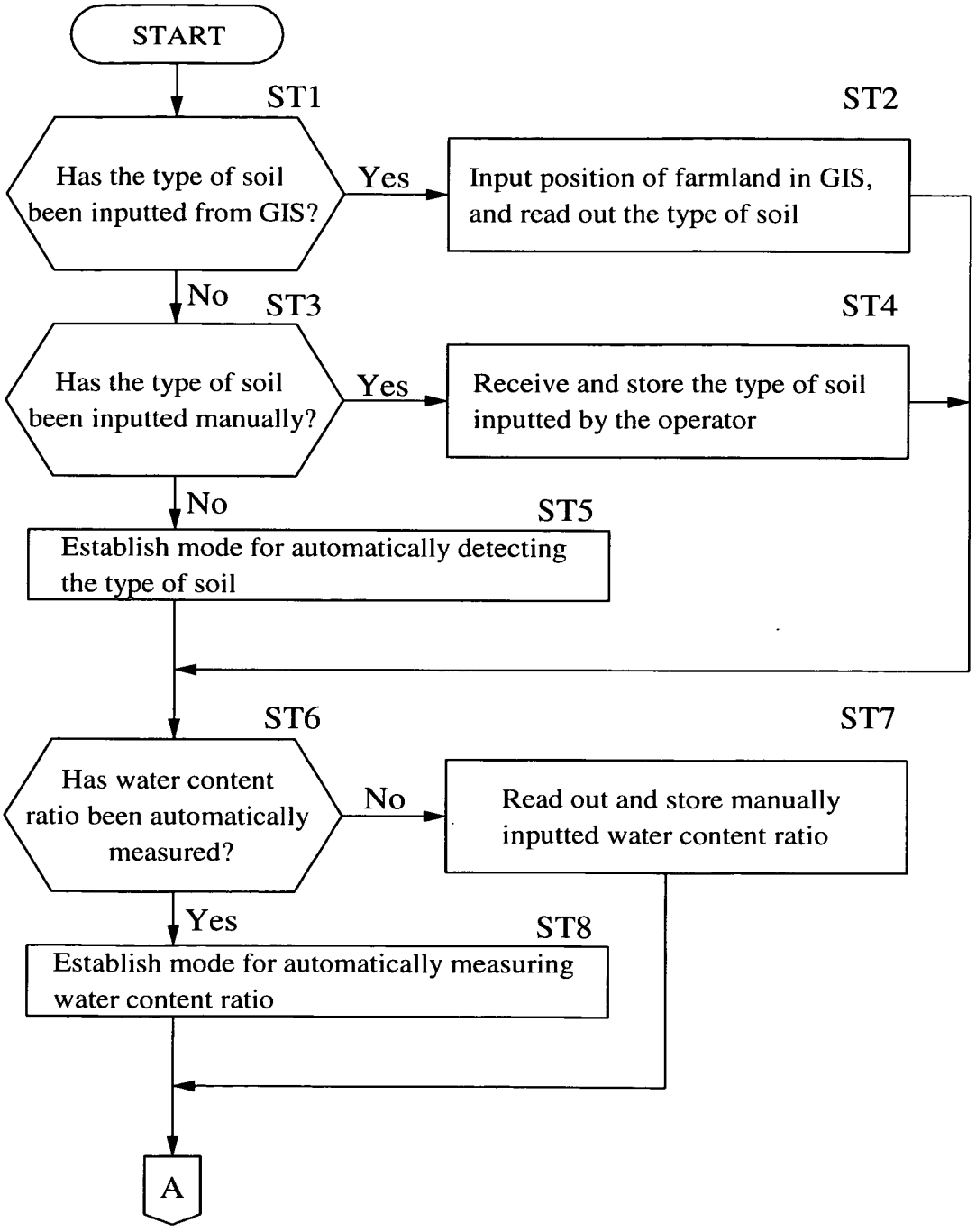

START
ST1
Has the type of soil been inputted from GIS?
Yes
ST2
Input position of farmland in GIS, and read out the type of soil
No
ST3
Has the type of soil been inputted manually?
Yes
ST4
Receive and store the type of soil inputted by the operator
No
ST5
Establish mode for automatically detecting the type of soil
ST6
Has water content ratio been automatically measured?
No
ST7
Read out and store manually inputted water content ratio
Yes
ST8
Establish mode for automatically measuring water content ratio
A

FIG.15

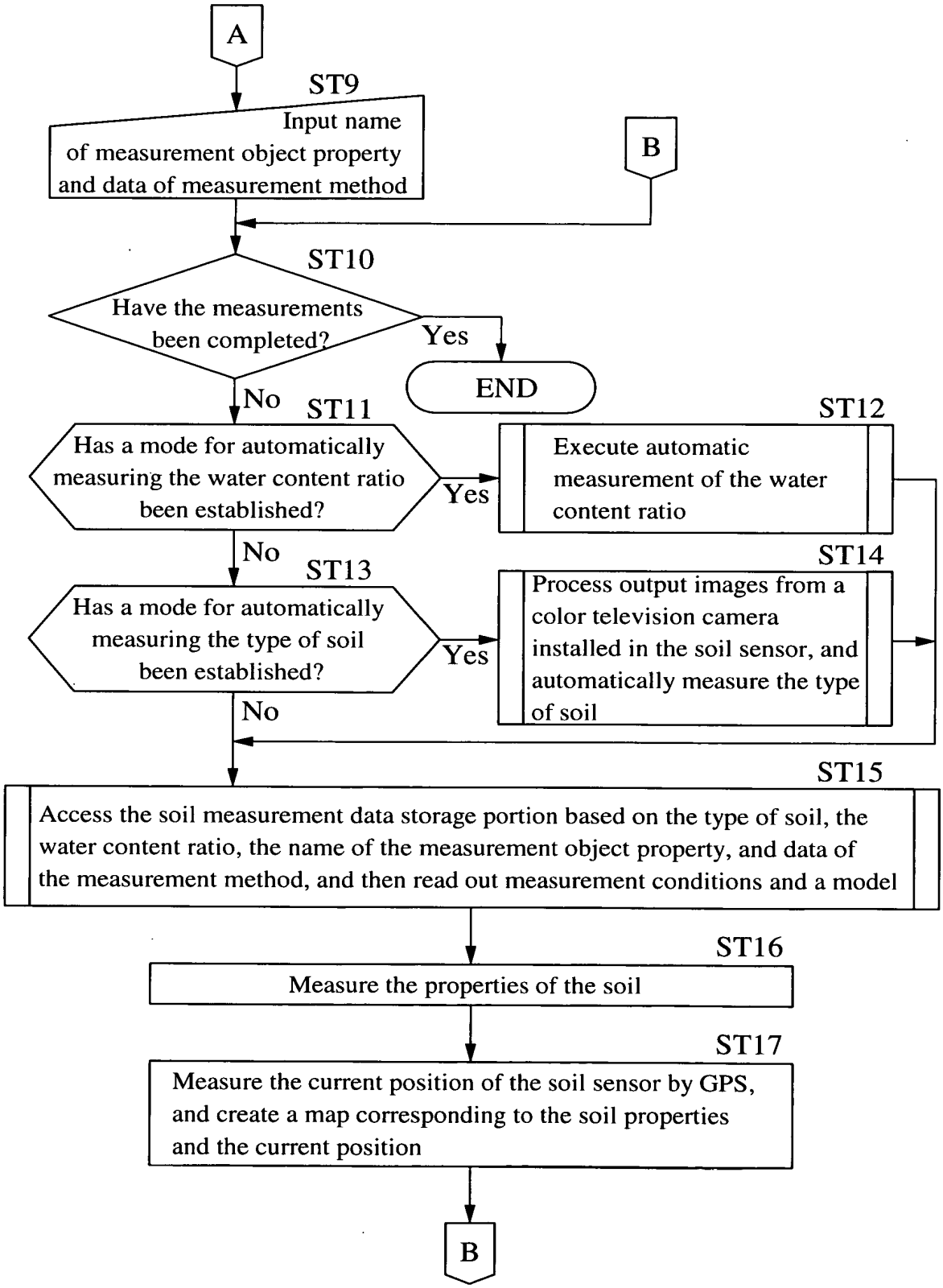

A
ST9
Input name of measurement object property and data of measurement method
B
ST10
Have the measurements been completed?
Yes
END
No
ST11
Has a mode for automatically measuring the water content ratio been established?
Yes
ST12
Execute automatic measurement of the water content ratio
No
ST13
Has a mode for automatically measuring the type of soil been established?
Yes
ST14
Process output images from a color television camera installed in the soil sensor, and automatically measure the type of soil
No
ST15
Access the soil measurement data storage portion based on the type of soil, the water content ratio, the name of the measurement object property, and data of the measurement method, and then read out measurement conditions and a model
ST16
Measure the properties of the soil
ST17
Measure the current position of the soil sensor by GPS, and create a map corresponding to the soil properties and the current position
B

FIG.16

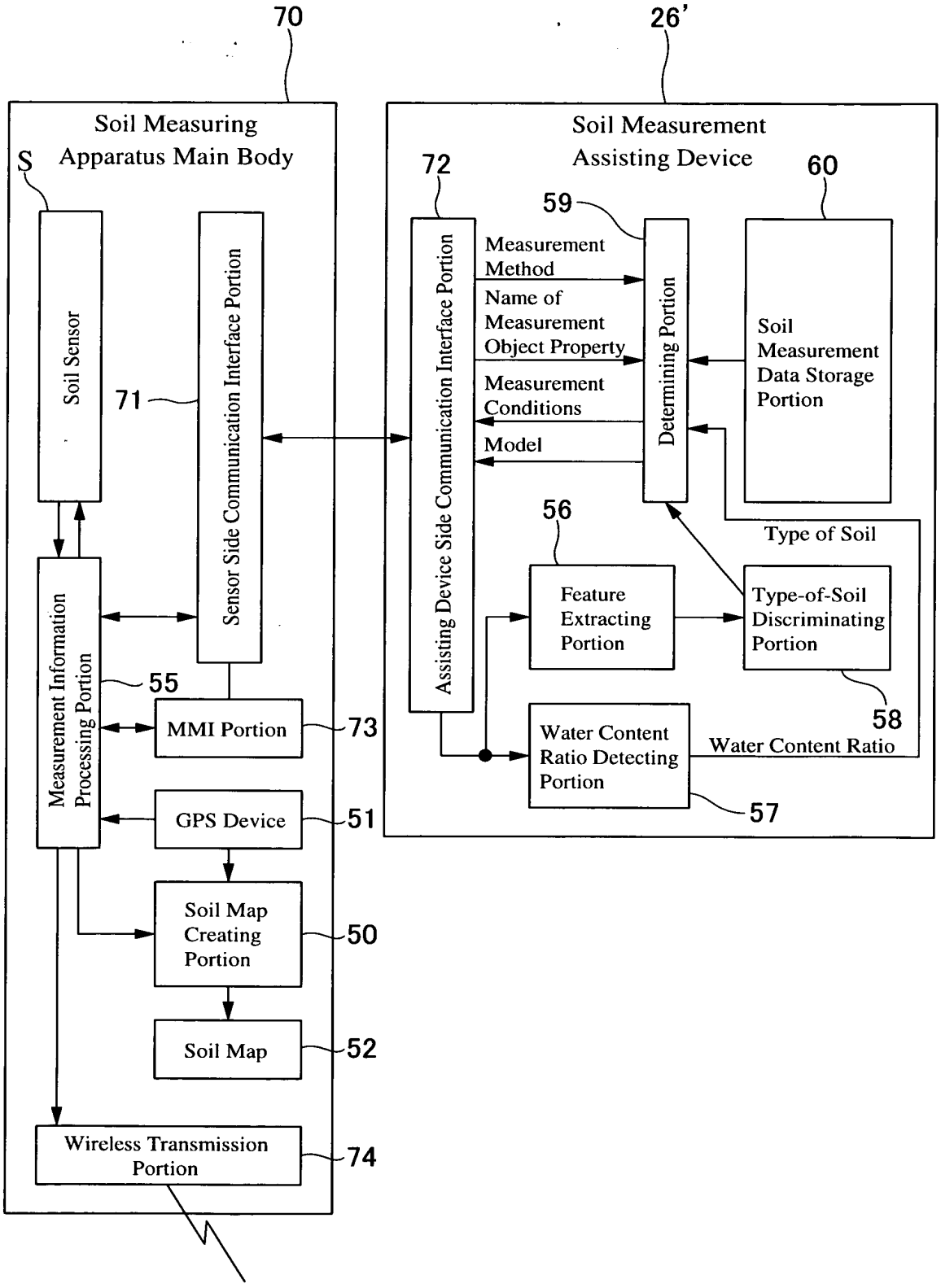

70
26'
Soil Measuring Apparatus Main Body
Soil Measurement Assisting Device
S
72
60
59
Soil Sensor
71
Sensor Side Communication Interface Portion
Measurement Method
Name of Measurement Object Property
Measurement Conditions
Model
Assisting Device Side Communication Interface Portion
Determining Portion
Soil Measurement Data Storage Portion
56
Type of Soil
Feature Extracting Portion
Type-of-Soil Discriminating Portion
58
Measurement Information Processing Portion
55
MMI Portion
73
GPS Device
51
Soil Map Creating Portion
50
Soil Map
52
Water Content Ratio Detecting Portion
Water Content Ratio
57
Wireless Transmission Portion
74

FIG.17

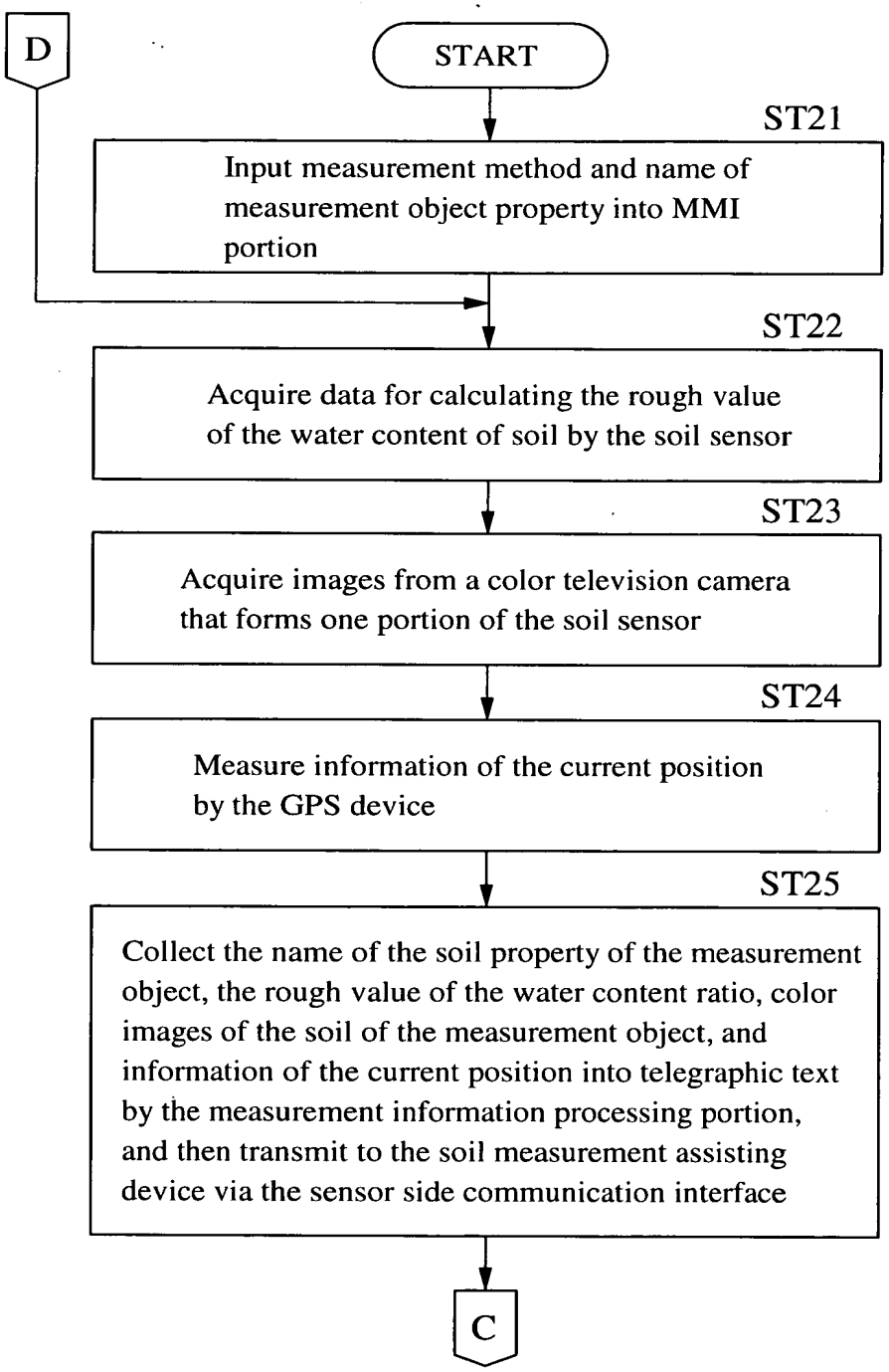

D
START
ST21
Input measurement method and name of measurement object property into MMI portion
ST22
Acquire data for calculating the rough value of the water content of soil by the soil sensor
ST23
Acquire images from a color television camera that forms one portion of the soil sensor
ST24
Measure information of the current position by the GPS device
ST25
Collect the name of the soil property of the measurement object, the rough value of the water content ratio, color images of the soil of the measurement object, and information of the current position into telegraphic text by the measurement information processing portion, and then transmit to the soil measurement assisting device via the sensor side communication interface
C

FIG.18

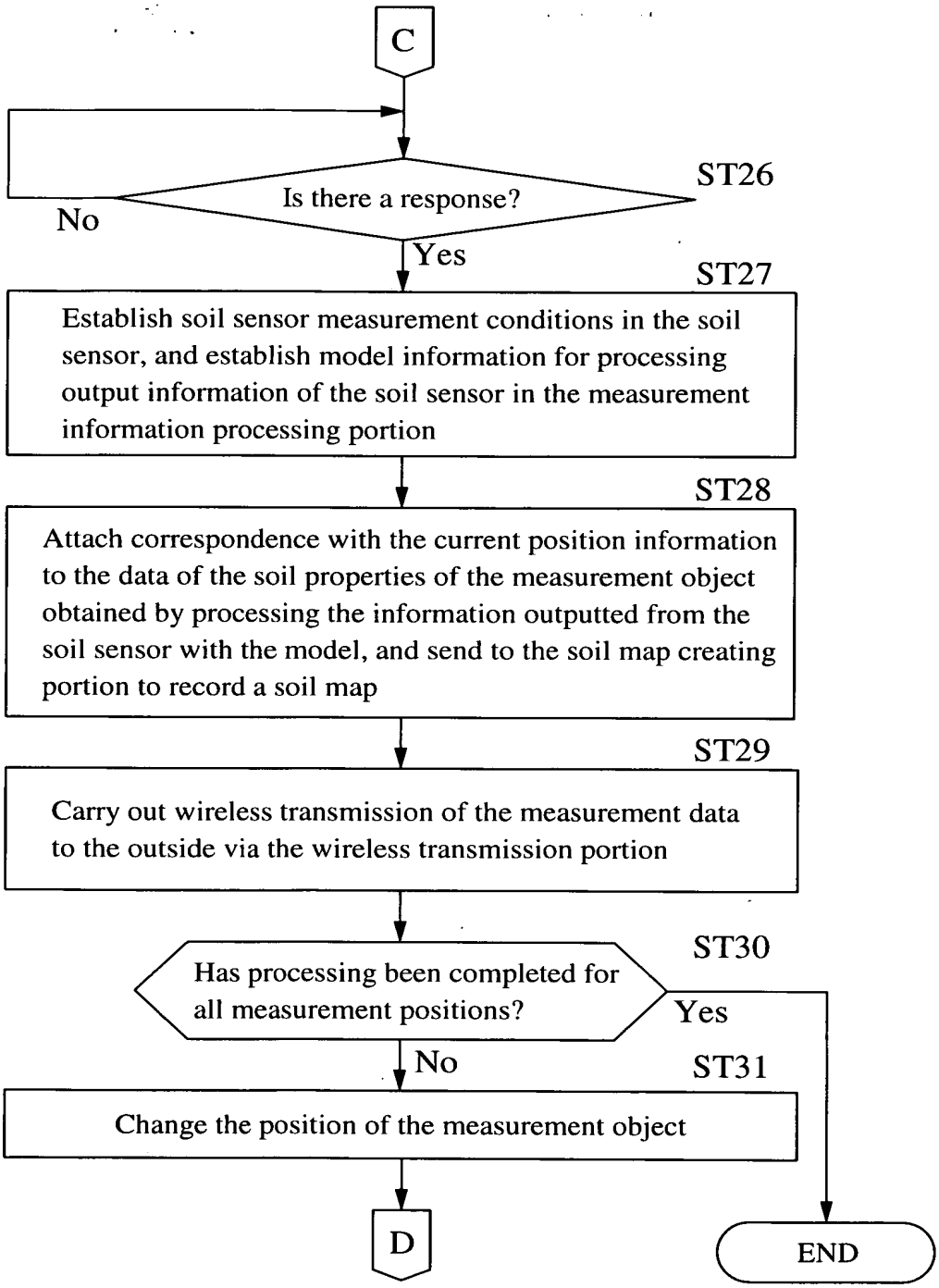

C
ST26
Is there a response?
No
Yes
ST27
Establish soil sensor measurement conditions in the soil sensor, and establish model information for processing output information of the soil sensor in the measurement information processing portion
ST28
Attach correspondence with the current position information to the data of the soil properties of the measurement object obtained by processing the information outputted from the soil sensor with the model, and send to the soil map creating portion to record a soil map
ST29
Carry out wireless transmission of the measurement data to the outside via the wireless transmission portion
ST30
Has processing been completed for all measurement positions?
Yes
No
ST31
Change the position of the measurement object
D
END

FIG.19

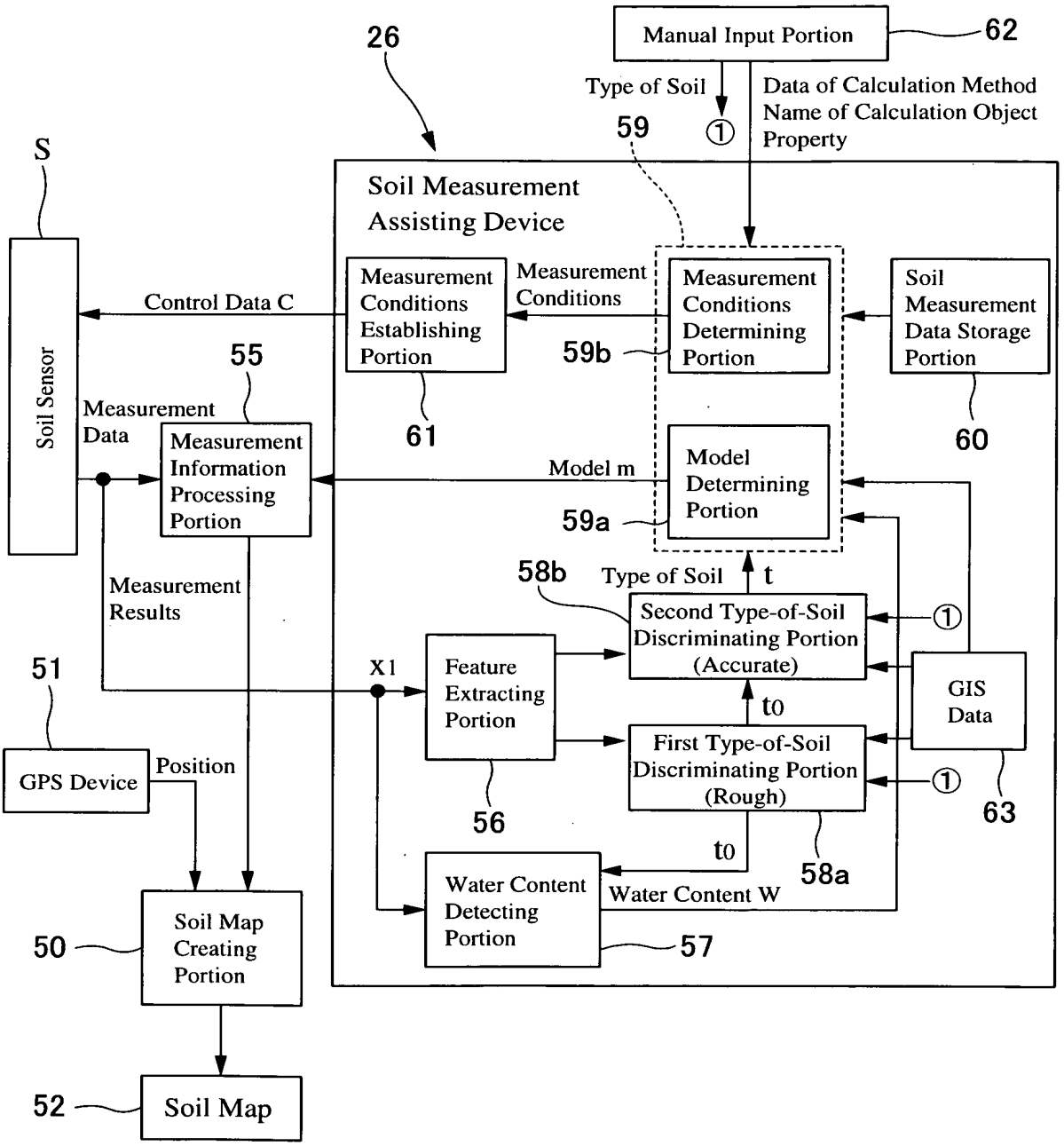

Manual Input Portion
62
26
Type of Soil
Data of Calculation Method
Name of Calculation Object
Property
59
①
S
Soil Measurement
Assisting Device
Measurement
Conditions
Establishing
Portion
Measurement
Conditions
Measurement
Conditions
Determining
Portion
Soil
Measurement
Data Storage
Portion
Control Data C
Soil Sensor
55
59b
Measurement
Data
Measurement
Information
Processing
Portion
61
60
Model m
Model
Determining
Portion
59a
58b
Type of Soil
t
Second Type-of-Soil
Discriminating Portion
(Accurate)
①
Measurement
Results
51
X1
Feature
Extracting
Portion
GIS
Data
t0
GPS Device
Position
First Type-of-Soil
Discriminating Portion
(Rough)
①
56
63
t0
58a
Water Content
Detecting
Portion
Water Content W
50
Soil Map
Creating
Portion
57
52
Soil Map

FIG.20

Definitions based on the International Soil Institute Method

Kind	Definitions : Based on Particle Diameter
Clay	Soil Particles Having a Particle Diameter below 0.002 mm
Silt	Soil Particles Having a Particle Diameter of 0.002 ~ 0.02 mm
Sand	Soil Particles Having a Particle Diameter of 0.02 ~ 2 mm

2003-04-02 09:50

FIG.21

Type of Soil (Main Types)	Definitions	Type of Soil (Subdivided Types)	Definitions
Heavy Clay Type	Clay Content above 45%	Heavy Clay Soil	Clay Content above 45%
Clay Type	Clay Content of 25 ~ 45%	Sandy Clay Soil	Sand above 55%
		Light Clay Soil	Sand below 55%+Silt below 45%
		Silty Clay Soil	Silt above 45%
Loamy Soil Type	Clay Content of 15 ~ 25%	Sandy Clay Loamy Soil	Sand above 80%
		Clay Loamy Soil	Sand of 55 ~ 85%
		Silty Clay Loamy Soil	Sand below 55% (Silt above 45%)
Sandy Soil Type	Clay Content below 15%	Loamy Sandy Soil	Sand above 85%+Clay Content above 5%
		Sandy Soil	Sand below 85%+Clay Content below 5%
		Sandy Loamy Soil	Sand of 65 ~ 85%
		Loamy Soil	Sand below 65%+Silt below 45%
		Silty Loamy Soil	Silt above 45%

10/030402

FIG.22

Contained Substances		Effect on Color	Specific Example
Iron Compounds	Free Iron	Red, Brown and Yellow become strong	Soil with good exposure to air, such as upland field soil, etc.
	Reduced Iron	Blue and Green become strong (Clay of the Gley Layer)	Oxygen Deficient Soil, such as paddy field soil
	Small Amount of Iron Compounds	Color becomes Gray, Light Gray	Deposits of volcanic ash and sand (Pyroclastic pumice flow sediment)
Manganese Compounds	Free Manganese	Black, Brown and Purple are supplied	For a paddy field with good drainage, the purple layer in the substrate of the surface soil will be visible
Humus Content		Black becomes deep to a large extent	Soil containing a large amount of organic matter, such as Andisol containing a amount of compost, etc.

Soil Attributes : The color tone becomes stronger when the amount of clay becomes larger.
Water Content : The color tone becomes lighter when the soil becomes drier.
Soil Formation Effects : Brown Woody Soil→Surface layer becomes brown ~ blackish brown(Warm Heavy Rain broad-leaved trees)
Podzol Soil→Bleaching causes color to become white ~ light gray(Cold Needle-leaved trees)
Laterite→Red soil rich in iron and alumina (tropical rain forest)
Andisol→Black ~ blackish brown (volcanic ash)
Peat・Muck→Black ~ blackish brown

FIG.23

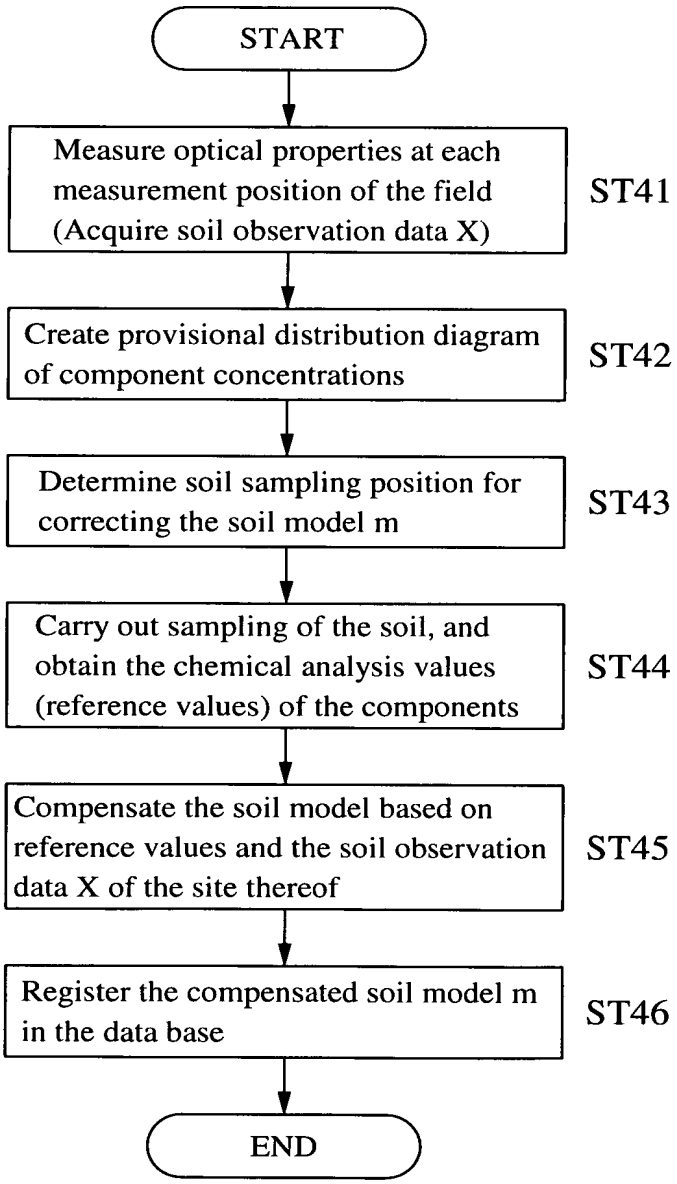

START
Measure optical properties at each measurement position of the field (Acquire soil observation data X)
ST41
Create provisional distribution diagram of component concentrations
ST42
Determine soil sampling position for correcting the soil model m
ST43
Carry out sampling of the soil, and obtain the chemical analysis values (reference values) of the components
ST44
Compensate the soil model based on reference values and the soil observation data X of the site thereof
ST45
Register the compensated soil model m in the data base
ST46
END

FIG.24

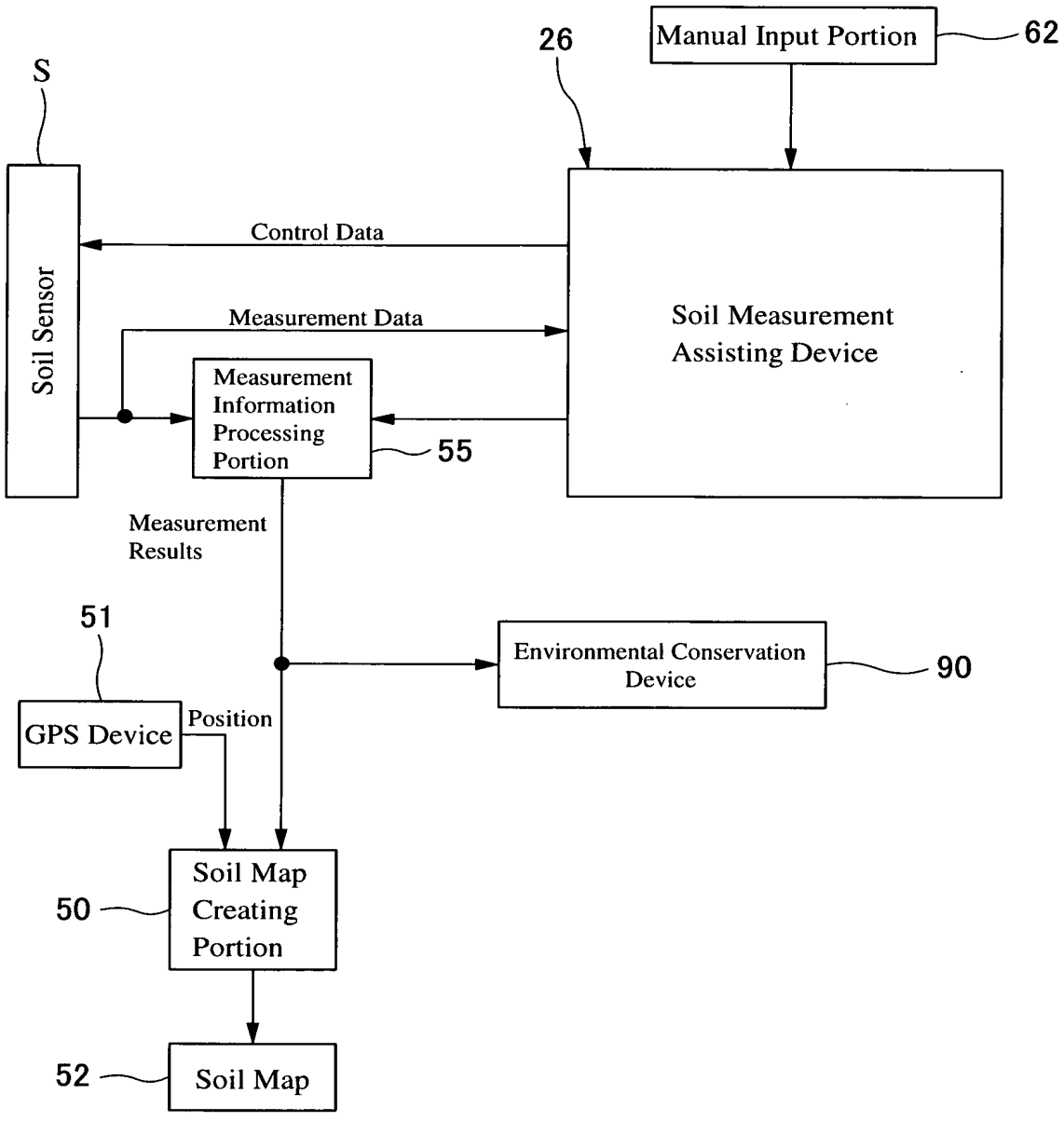

S
26
Manual Input Portion
62
Soil Sensor
Control Data
Measurement Data
Soil Measurement Assisting Device
Measurement Information Processing Portion
55
Measurement Results
51
Environmental Conservation Device
90
GPS Device
Position
Soil Map Creating Portion
50
52
Soil Map

FIG.25

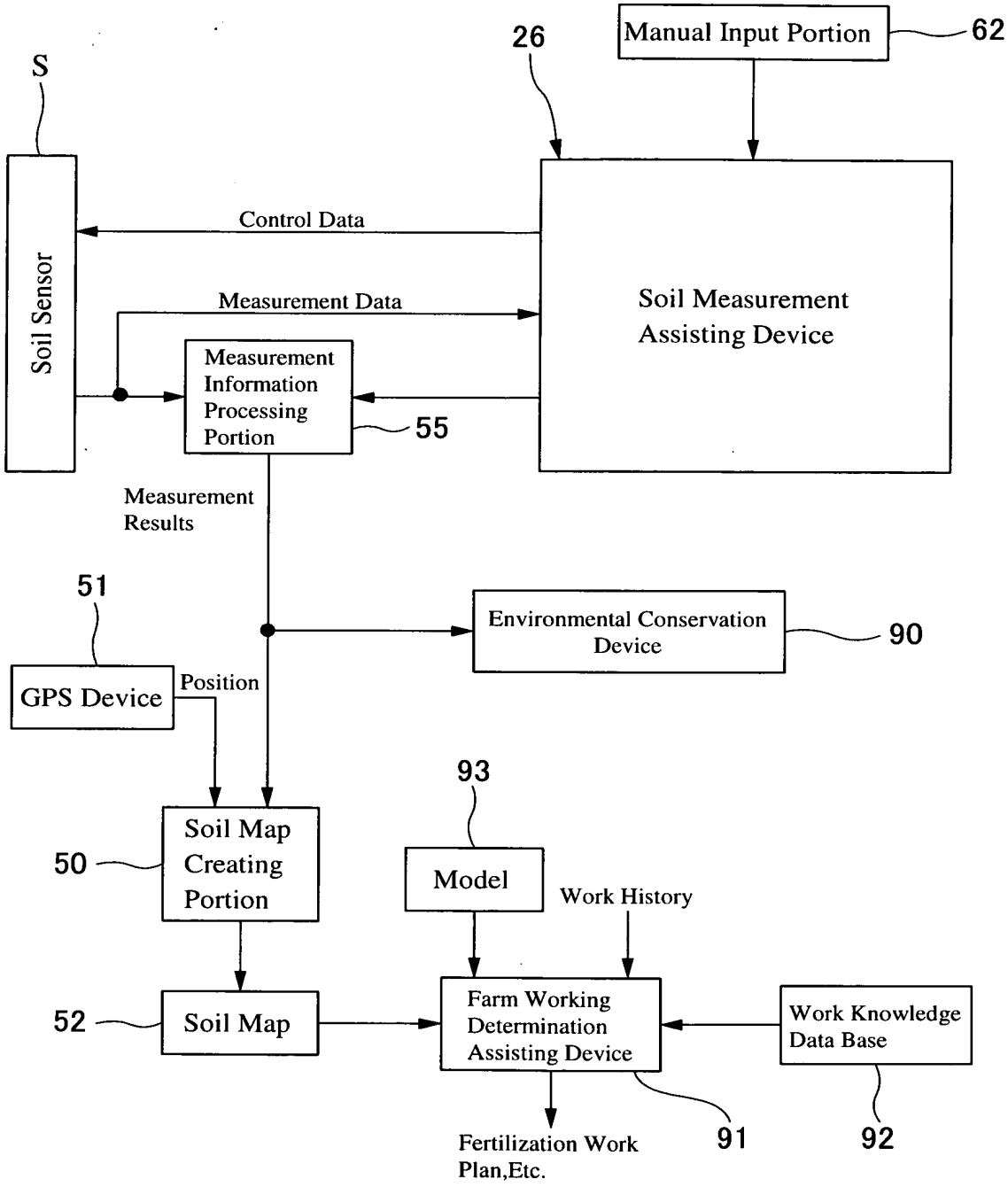

S
26
Manual Input Portion
62
Soil Sensor
Control Data
Measurement Data
Soil Measurement Assisting Device
Measurement Information Processing Portion
55
Measurement Results
51
GPS Device
Position
Environmental Conservation Device
90
93
Soil Map Creating Portion
50
Model
Work History
52
Soil Map
Farm Working Determination Assisting Device
Work Knowledge Data Base
Fertilization Work Plan,Etc.
91
92

FIG.26

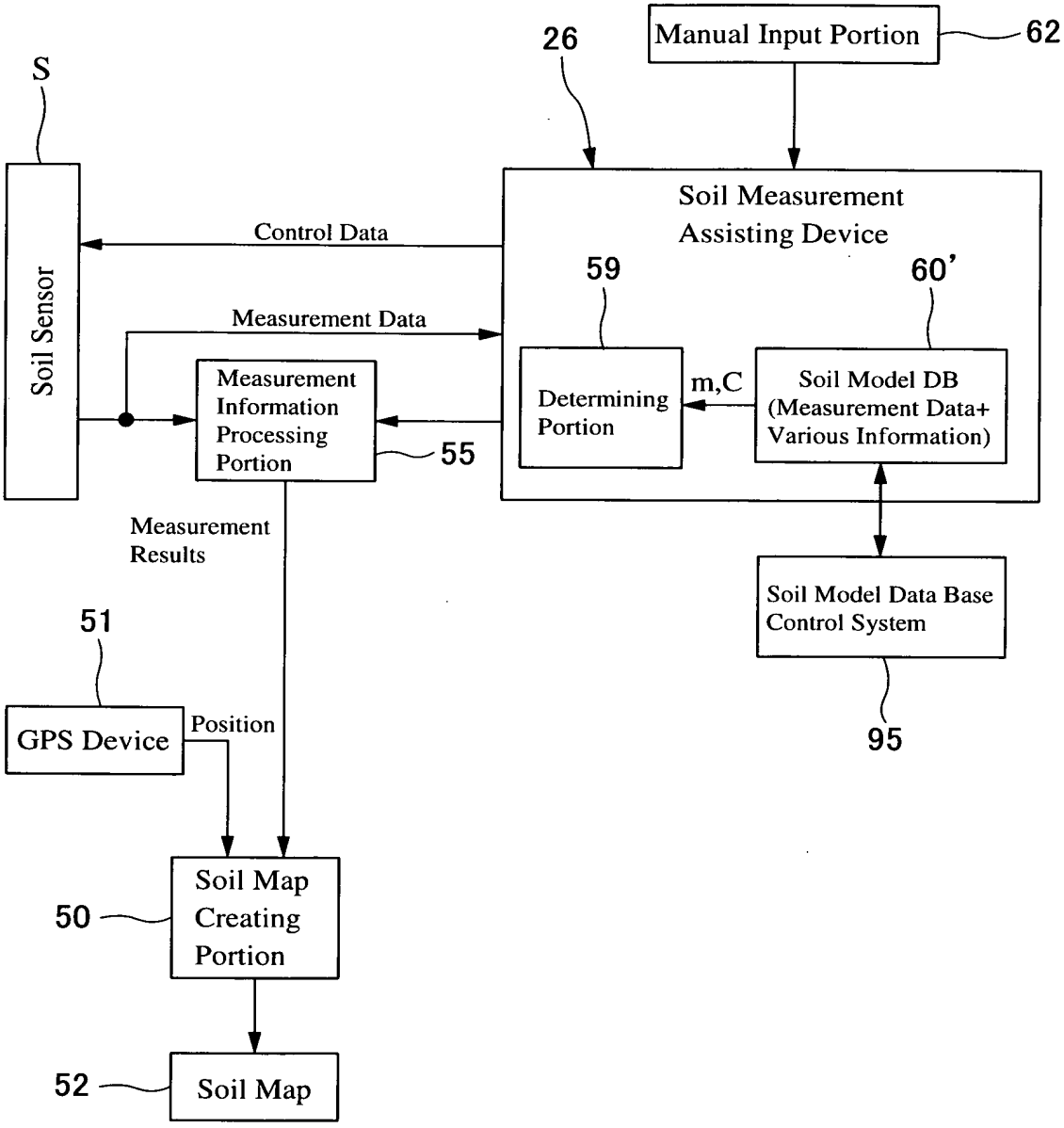

S
26
Manual Input Portion
62
Soil Sensor
Control Data
Soil Measurement
Assisting Device
59
60'
Measurement Data
Measurement
Information
Processing
Portion
55
Determining
Portion
m,C
Soil Model DB
(Measurement Data+
Various Information)
Measurement
Results
Soil Model Data Base
Control System
95
51
GPS Device
Position
Soil Map
Creating
Portion
50
52
Soil Map

FIG.27

Name of Measurement Object Property	Type of Soil	Water Content	Weather Conditions	Soil Measurement Information (Control Data + Soil Measurement Model)	Advertisement Information	Cultivation Recipe + Actual Harvest Results Presentation	Farmland Location Information	Soil Working Instructions Information	
NO_3-N Concentration	Sand Loam	Small	Hot	m1 C1	Seed Advertisements http:// Agricultural Chemical Advertisements http://	S1 (Cultivation Recipe + Actual Harvest Results) S2	P1 (Location, Area, Owner, Farmer, Address) P2, P3	U1	
NO_3-N Concentration	Sand Loam	Large	Cold	m2 C2	Fertilizer Advertisements http://	S3	P4	U2	
Soil Organic Materials	Clay	Small	Dry	m3 C3	Information on Soil Judgment Services	S4	P5	U3	
Soil Organic Materials	Clay	Large	Heavy Rain	m4 C4	Advertisements on crop field Lending and Borrowing	S5	P6	U4	

FIG.28

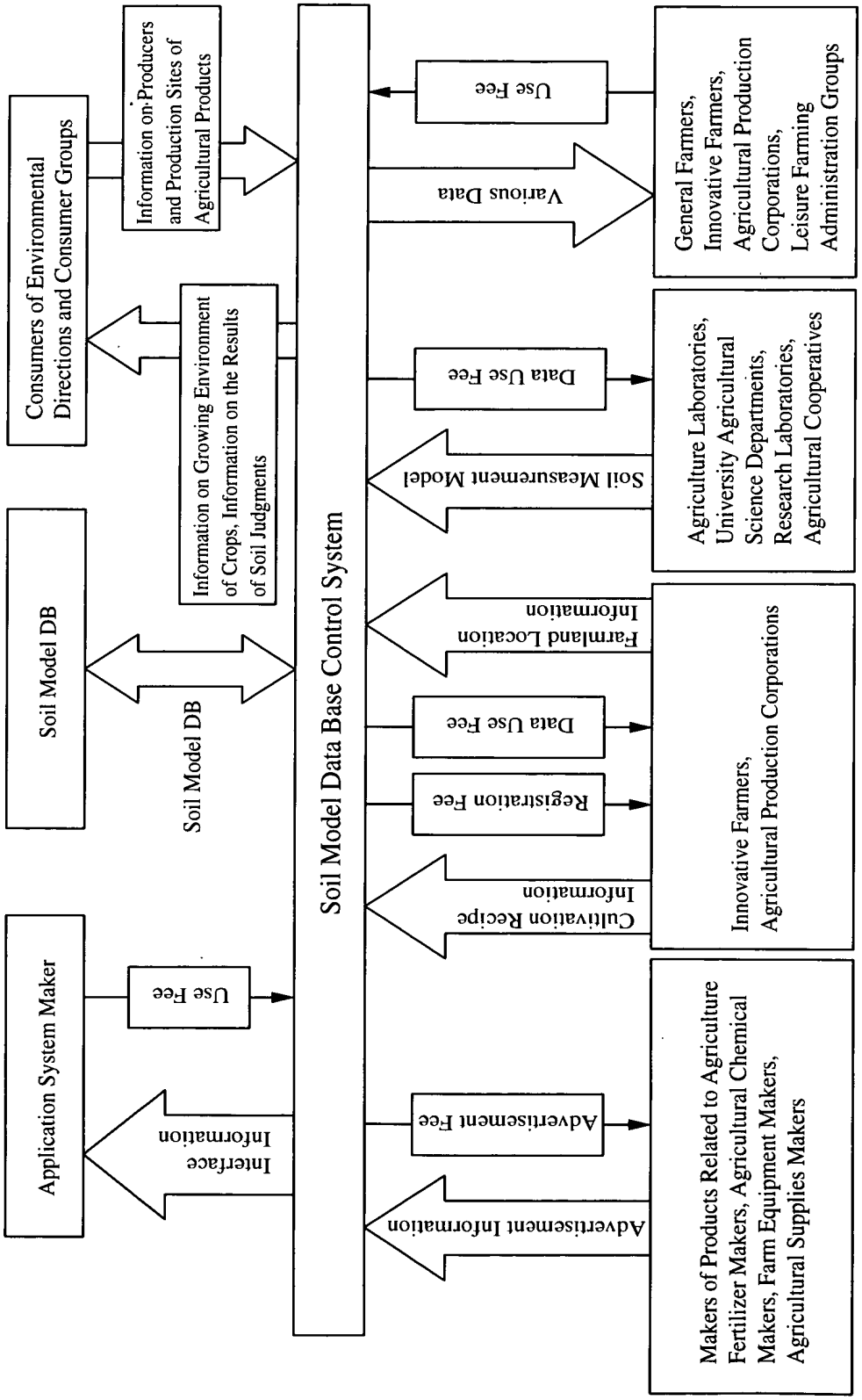

Soil Model Data Base Control System
Application System Maker
Use Fee
Interface Information
Soil Model DB
Soil Model DB
Information on Growing Environment of Crops, Information on the Results of Soil Judgments
Consumers of Environmental Directions and Consumer Groups
Information on Producers and Production Sites of Agricultural Products
Use Fee
Various Data
General Farmers, Innovative Farmers, Agricultural Production Corporations, Leisure Farming Administration Groups
Data Use Fee
Soil Measurement Model
Agriculture Laboratories, University Agricultural Science Departments, Research Laboratories, Agricultural Cooperatives
Farmland Location Information
Data Use Fee
Registration Fee
Cultivation Recipe Information
Innovative Farmers, Agricultural Production Corporations
Advertisement Fee
Advertisement Information
Makers of Products Related to Agriculture Fertilizer Makers, Agricultural Chemical Makers, Farm Equipment Makers, Agricultural Supplies Makers

FIG.29

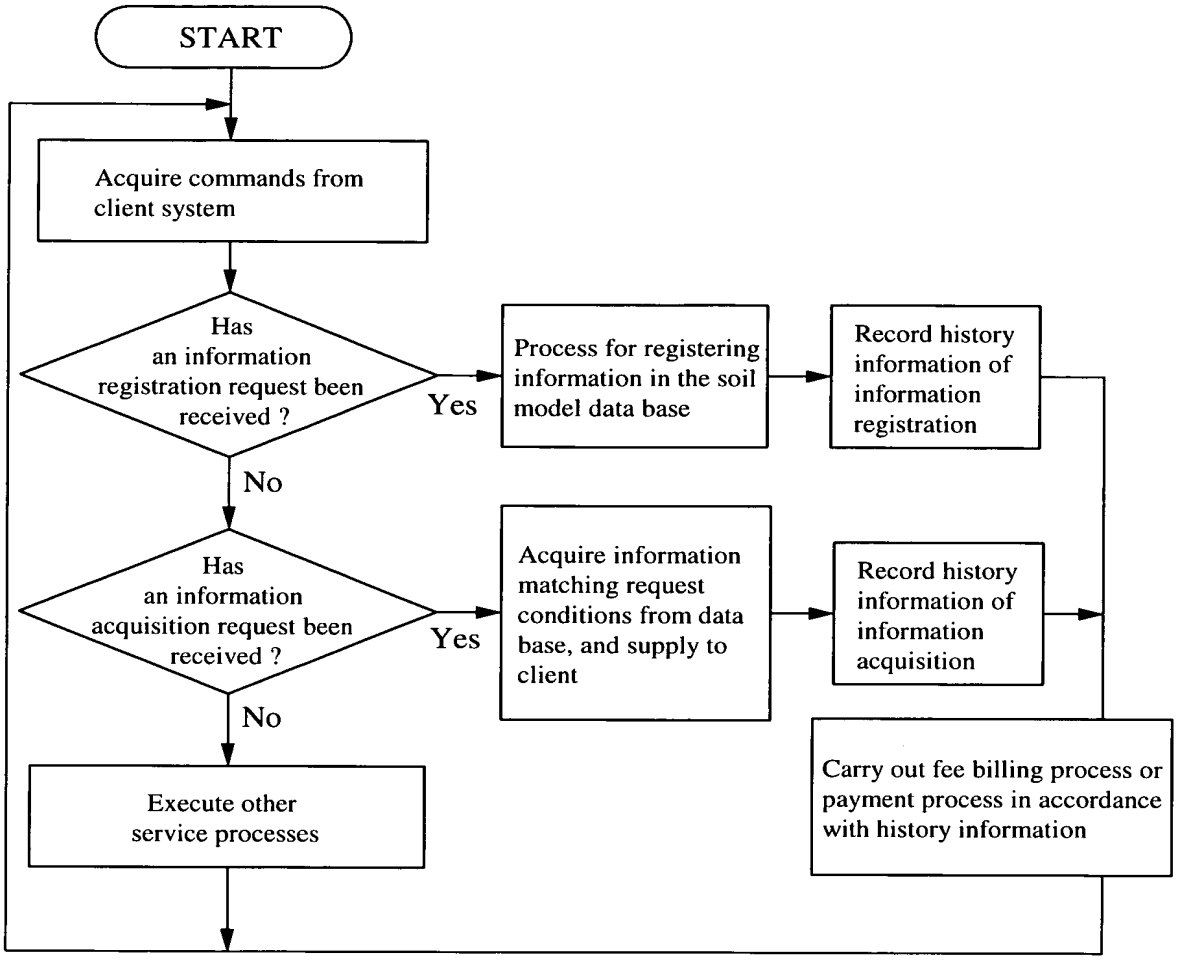

START
Acquire commands from client system
Has an information registration request been received ?
Yes
Process for registering information in the soil model data base
Record history information of information registration
No
Has an information acquisition request been received ?
Yes
Acquire information matching request conditions from data base, and supply to client
Record history information of information acquisition
No
Execute other service processes
Carry out fee billing process or payment process in accordance with history information

FIG.30

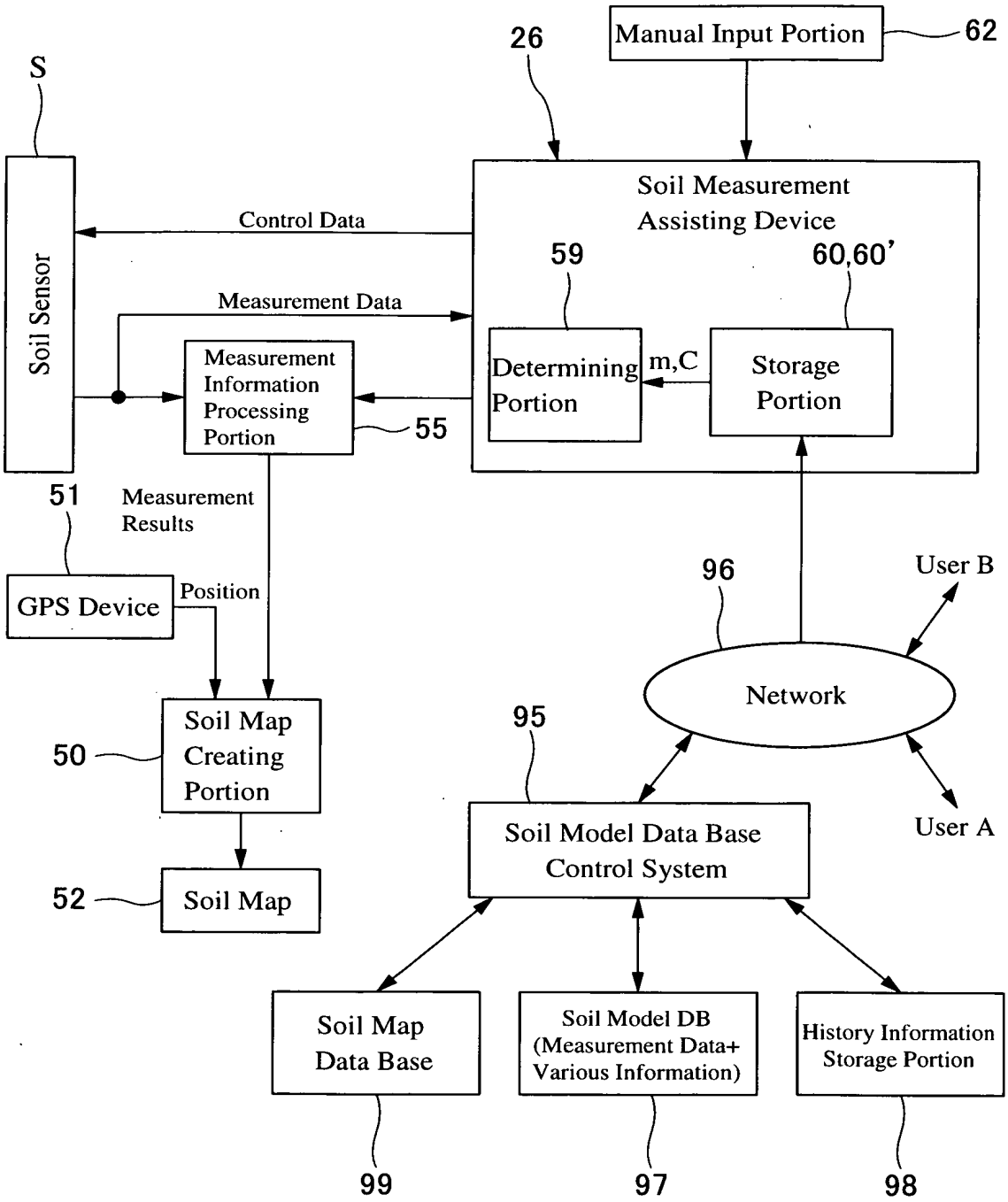

S
26
Manual Input Portion
62
Soil Sensor
Control Data
Soil Measurement
Assisting Device
59
60,60'
Measurement Data
Measurement
Information
Processing
Portion
55
Determining
Portion
m,C
Storage
Portion
51
Measurement
Results
GPS Device
Position
96
User B
Network
95
Soil Map
Creating
Portion
50
Soil Model Data Base
Control System
User A
52
Soil Map
Soil Map
Data Base
Soil Model DB
(Measurement Data+
Various Information)
History Information
Storage Portion
99
97
98

FIG.31

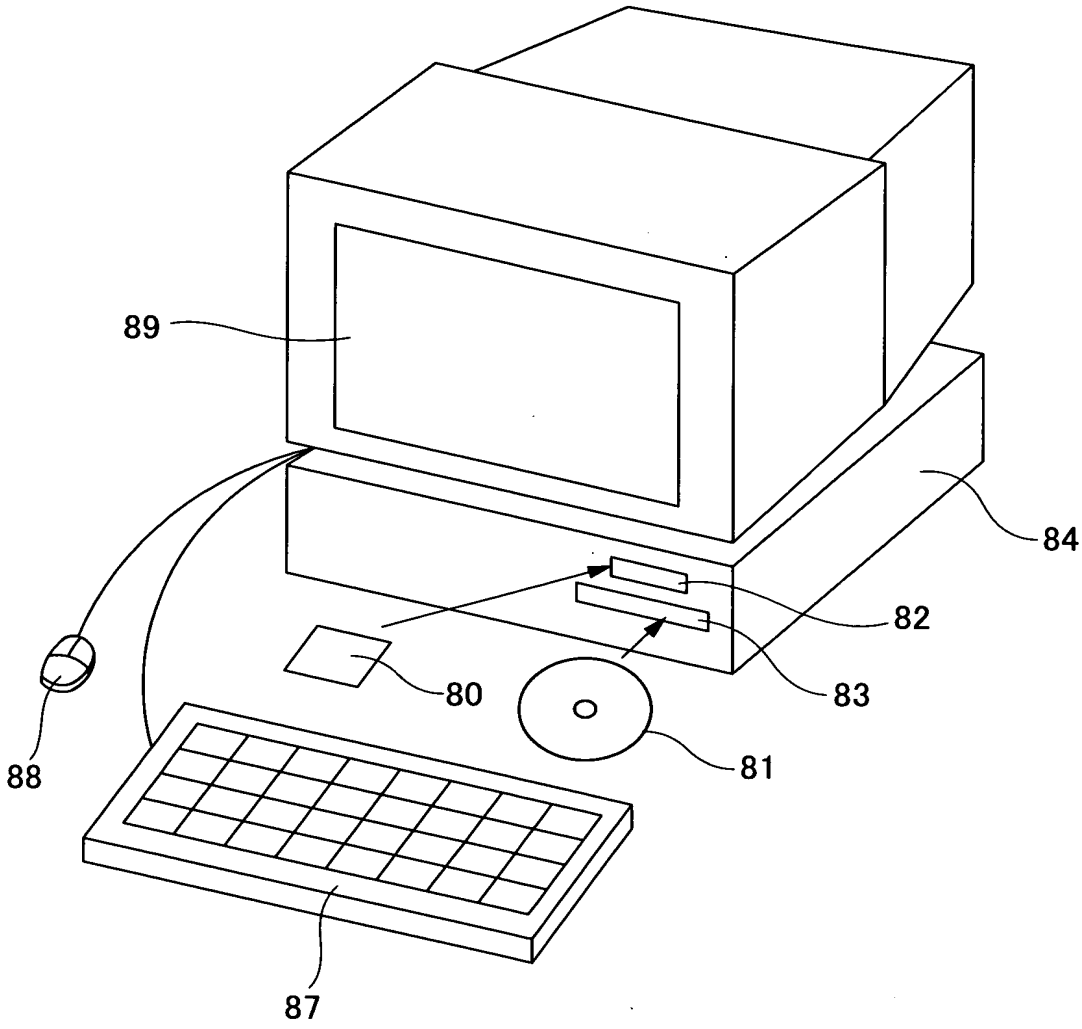
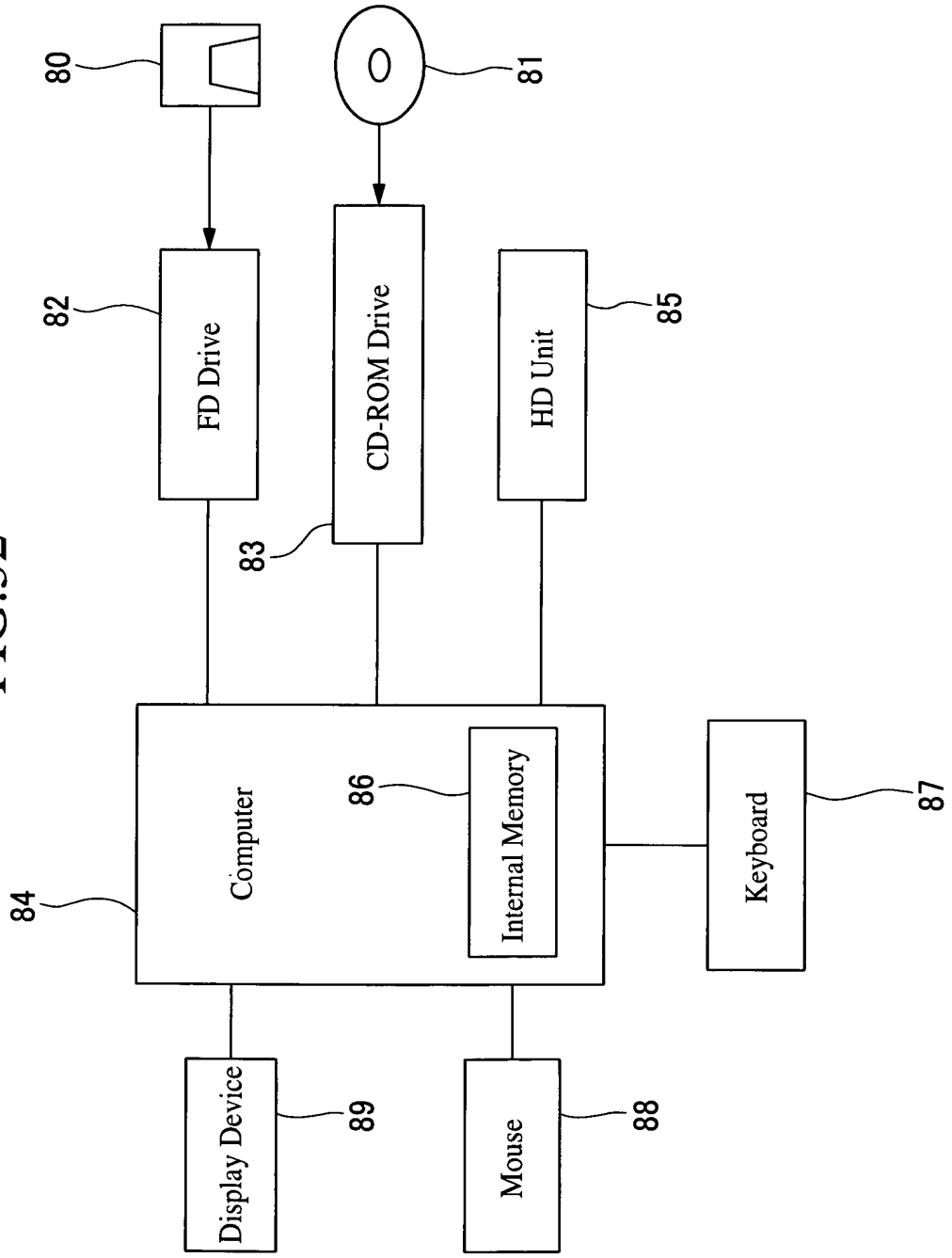


FIG.32


80
81
82
FD Drive
CD-ROM Drive
83
HD Unit
85
Computer
84
86
Internal Memory
Keyboard
87
Display Device
89
Mouse
88